IRON TOTAL MAXIMUM DAILY LOAD (TMDL)

LAKE OKEECHOBEE

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EPA United States Environmental Protection Agency

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ABBREVIATIONS

CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
HUC	Hydrologic Unit Code
LA	Load Allocation
MCL	Maximum Contaminant Level
MG	Milligram
ML	Milliliter
MOS	Margin of Safety
NPDES	National Pollutant Discharge Elimination System
NTU	Nephalometric Turbidity Unit
SFWMD	South Florida Water Management District
TMDL	Total Maximum Daily Load
UG	Microgram
WBID	Water Body Identification
WLA	Waste Load Allocation

SUMMARY SHEET
TOTAL MAXIMUM DAILY LOAD

1. **303(d) Listed Waterbody Information**
   State: Florida
   Counties: Okeechobee, Martin, Palm Beach, Hendry, Glades
   Major River Basin: Lake Okeechobee Basin (HUC 03090201)
   Impaired waterbodies (1998 303(d) list):

WBID	Segment Name	Constituent(s)
3212D	Lake Okeechobee	Iron
3212E	Lake Okeechobee	Iron
3212G	Lake Okeechobee	Iron

2. **TMDL endpoint:** Class I iron water quality criterion 0.3 mg/L

3. **Iron Allocation:**

Waterbody	WLA	LA	MOS	TMDL
WBIDs 3212D, 3212E, 3212G	0	51% reduction	Explicit (3%)	51% reduction

4. **Public Notice Date:** September 30, 2003

5. **Endangered Species:** yes

6. **Lead on TMDL:** EPA

7. **TMDL considers point or non-point sources:** Non-point Only

8. **Major NPDES dischargers into surface water:** none

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1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires states to submit to the United States Environmental Protection Agency (USEPA) lists of surface waters that do not meet applicable water quality standards after implementation of technology-based effluent limitations. A Total Maximum Daily Load (TMDL) must then be established for these impaired waters on a prioritized schedule. TMDLs establish the maximum amount of a pollutant that a water body can assimilate without causing exceedances of water quality standards. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991).

Total Maximum Daily Loads are quantitative analyses of water bodies where one or more water quality standards are not being met. In essence, TMDLs describe the amount of each pollutant a water body can receive without violating standards, and are characterized as the sum of wasteload allocations, load allocations, and a margin of safety to account for uncertainties. Wasteload allocations are pollutant loads attributable to existing and future point sources, such as discharges from industry and sewage facilities. Load allocations are pollutant loads attributable to existing and future nonpoint sources and natural background. Nonpoint sources include runoff from farms, forests, urban areas, and natural sources, such as decaying organic matter and nutrients in soil (FDEP 2001a, http://www.dep.state.fl.us/water/tmdl/faq.htm).

The State of Florida Department of Environmental Protection (FDEP) developed a statewide, watershed-based approach to water resource management. Under this watershed management approach, water resources are managed on the basis of natural boundaries, such as river basins, rather than political boundaries. The watershed management approach is the framework FDEP uses for implementing TMDLs. The state's 52 basins are divided into five groups. Water quality is assessed in each group on a rotating five-year cycle. The Lake Okeechobee Basin, a Group 1 Basin, was first assessed in 2000 with plans to revisit water management issues in 2005 (Figure 1). FDEP established five water management districts responsible for managing groundwater and surface water. The Lake Okeechobee Basin is in the South Florida Water Management District (SFWMD).

For the purpose of planning and management, basins are divided into planning units. A planning unit is either an individual primary tributary basin or a group of adjacent primary tributary basins with similar characteristics. These planning units contain smaller, hydrological units called drainage basins, which are further divided into water segments. A water segment usually contains only one unique waterbody type (stream, lake, canal, etc.) and is about five square miles. Unique waterbody identification (WBIDs) numbers are assigned to each water segment.

2.0 PROBLEM DEFINITION

Florida Class I water bodies are designated as potable water supply (drinking water). Florida has designated Lake Okeechobee as a Class I water. Florida's final Clean Water Act 1998 Section 303(d) list identified WBIDs in the Lake Okeechobee Basin that do not support water quality standards. FDEP identified three portions of Lake Okeechobee as being impaired for iron: WBIDs 3212D, 3212E, and 3212G (Figure 1 and Table 1) (FDEP 2001b). USEPA is responsible for developing the iron TMDLs for Lake Okeechobee.

Table 1. Lake Okeechobee WBIDs requiring an iron TMDL.

WBID	Name	Planning Unit	Parameter of Concern
3212D	Lake Okeechobee	Lake Okeechobee	Iron
3212E	Lake Okeechobee	Lake Okeechobee	Iron
3212G	Lake Okeechobee	Lake Okeechobee	Iron

The TMDLs addressed in this document are being established pursuant to USEPA commitments in the 1998 Consent Decree in the Florida TMDL lawsuit (Florida Wildlife Federation, et al. v. Carol Browner, et al., Civil Action No. 4: 98CV356-WS, 1998).

The format of the remainder of this report is as follows: Chapter 3 is a general description of the Lake Okeechobee watershed; Chapter 4 describes the water quality standard and target criteria for the TMDL; Chapter 5 describes the development of the iron TMDL.

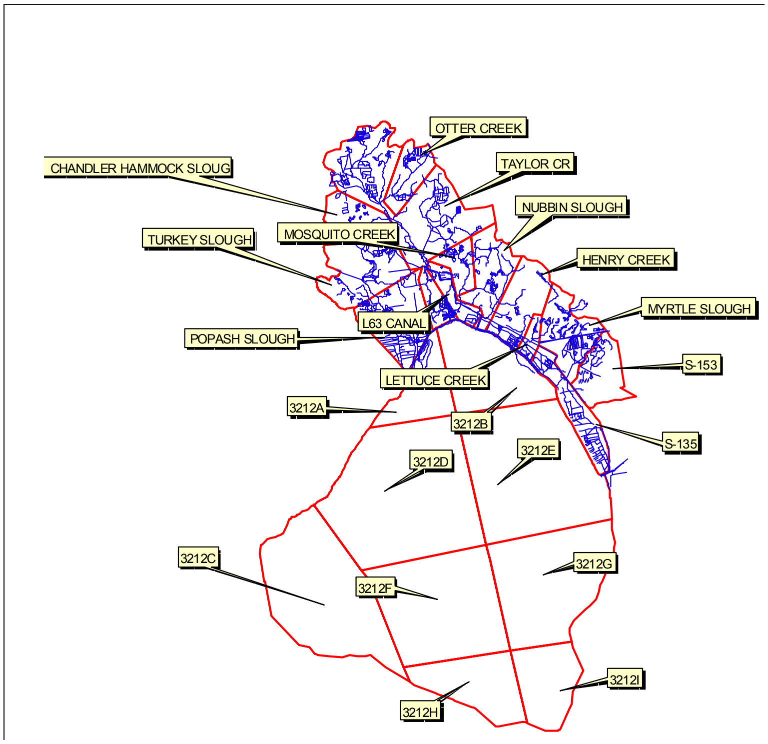

Figure 1. Lake Okeechobee Waterbody Identification Numbers (WBIDs).

3.0 WATERSHED DESCRIPTION

Lake Okeechobee is a large (700 square mile, 450,000 acre), shallow (average depth about 9 feet), eutrophic lake. The designated use is Class I, potable water, and the lake directly supplies drinking water to five communities around the lake. The lake is a multi-purpose reservoir that provides drinking water for urban areas, irrigation for agricultural lands, recharge for aquifers, fresh water for the Everglades, habitat for fish and waterfowl, flood control, recreation and navigation (FDEP 2001b).

The lake's watershed encompasses about 1,872,000 acres (2900 square miles). The Lake Okeechobee Surface Water and Management Plan (SFWMD 2003) identifies 34 basins that discharge into the lake, most of which are located to the north and northwest. The major basins in terms of discharge to the lake are the Kissimmee River, Fisheating Creek and the Taylor Creek/Nubbin Slough (S-191) basin. In addition, water from 2 basins within the Everglades Agricultural Area to the south, S-2 and S-3, is backpumped into the lake during flood or emergency water conditions.

Land use within the watershed is dominated by agriculture (62%), with another 34% classified as wetlands/water, and only 3% classified as urban. Major agricultural land uses include improved pasture, sugarcane, rangeland, unimproved pasture, and citrus groves (FDEP 2001b).

4.0 WATER QUALITY STANDARD AND TARGET IDENTIFICATION

As shown below, iron concentrations in Lake Okeechobee exceed water quality standards. However, review of iron data in south Florida ground water and surface water indicate that iron is commonly found at concentrations that exceed the drinking water criterion. These levels appear to represent iron concentrations not impacted by anthropogenic sources. A review of water quality standards and iron conditions follows.

4.1 Water Quality Standards

Florida Class I water bodies are designated as potable water supply. Florida has designated Lake Okeechobee as a Class I water. Florida's Class I water quality criterion for iron is 0.3 mg/L.

The following description of drinking water standards is taken from USEPA, 1992:

> The USEPA has established National Primary Drinking Water Regulations that set mandatory water quality standards for drinking water contaminants. These are enforceable standards called "maximum contaminant levels" or "MCLs", which are established to protect the public against consumption of drinking water contaminants that present a risk to human health. An MCL is the maximum allowable amount of a contaminant in drinking water that is delivered to the consumer.
>
> In addition, USEPA has established National Secondary Drinking Water Regulations that set non-mandatory water quality standards for 15 contaminants. USEPA does not enforce these "secondary maximum contaminant levels" or "SMCLs." They are established only as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color and odor. These contaminants are not considered to present a risk to human health at the SMCL. USEPA believes that if these contaminants are present in drinking water at levels above these standards, the contaminants may cause the water to appear cloudy or colored, or to taste or smell bad. This may cause people to stop using water from their public water system even though the water is actually safe to drink. Secondary standards are set to give public water systems some guidance on removing these chemicals to levels that are below what most people will find to be noticeable.
>
> Noticeable effects for iron above the SMCL may include rusty color, sediment, metallic taste, and reddish or orange staining.

The 0.3 mg/L set by USEPA for iron is a secondary maximum contaminant level and applies to potable water. There is no evidence that iron in Lake Okeechobee raw surface water presents a risk to human health or the environment. It should also be noted that the public drinking water providers that use Lake Okeechobee as a drinking water source do not employ any additional treatment technology because of iron. A filtration process that is already in place removes the iron. Florida applies their Class I water quality criteria to raw water rather than the treated drinking water or at the tap for Clean Water Act purposes.

Florida's Class III water bodies are designated for recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. Florida's Class III fresh water quality criterion for iron is 1.0 mg/L, about three times higher than the 0.3 mg/L drinking water standard that is applied to Lake Okeechobee. All tributaries to the lake have been designated as Class III waters.

4.2 Iron in the Environment

The element iron is a natural, abundant and widespread constituent of rocks, sediments and soils. Water that is naturally colored is often high in iron. The natural occurrence of 1.0 to 10 mg/L of iron in groundwater is not uncommon (Hem 1970, Manahan 1979). Manahan also notes that iron is soluble under reducing conditions, such as those that commonly occur in groundwater or lake bottom waters. Iron is an undesirable solute in water because of formation of $Fe(OH)_3$ deposits, commonly referred to as rust.

Concentrations of only a few tenths of a milligram per liter of iron can make water unsuitable for some uses. Iron concentrations in water are responsive to chemical equilibria. Variables of principal importance that influence iron solubility include pH and redox potential, and dissolved carbon dioxide and sulfur species. The oxide and sulfide species of iron minerals are usually the principal sources from which the dissolved iron of groundwater is found. In addition, since iron is an essential element in both plant and animal metabolism, iron is to be expected in organic wastes and plant products in soils (Hem 1970).

4.3 Iron Conditions in Lake Okeechobee

South Florida Water Management District (SFWMD) provided a data summary for iron in Lake Okeechobee from 1996-2002 at 50 water quality sampling stations (Appendix A). Out of 620 data points, 278 (45%) exceeded the Class I water quality criterion of 0.3 mg/L. The arithmetic average iron concentration is 0.574 mg/L, while the median is 0.373 mg/L, both of which exceed the 0.300 mg/L drinking water criterion. SFWMD monitors eight long-term lake stations, L001 – L008, for water quality. All average and median iron concentrations for all eight stations exceed the 0.3 mg/L criterion, with station medians ranging from 0.355 mg/L to 1.125 mg/L, and arithmetic means ranging from 0.571 mg/L to 1.230 mg/L. The stations with the lowest iron, L007 and L005, are the stations farthest to the south and west, respectively. The stations with the highest iron, (L004, L003, L006 and L008) are the four most interior stations (see SFWMD 2003, page 52 for station locations: http://www.sfwmd.gov/koe_section/2_lakeokee.html).

Statistical analysis indicates that iron in Lake Okeechobee is very strongly associated with turbidity ($r^2 = 0.90$) and processes within the lake (Figure 2). This suggests that controlling turbidity would control iron. Based on this relationship, an iron concentration of 0.3 mg/L corresponds to turbidity of about 10.5 NTU. When lake turbidity is less than 10.5 NTU, there is a 90% probability that iron will meet the water quality standard in raw lake water. Florida recently adopted and USEPA approved a phosphorus TMDL for Lake Okeechobee.

Unconsolidated sediments in the lake are known to resuspend with wind events. Scientists have noted a strong correlation between wind velocity and lake total phosphorus, which could be explained by resuspension of phosphorus-rich sediments (Maceina and Soballe 1990 as cited by Havens 1997).

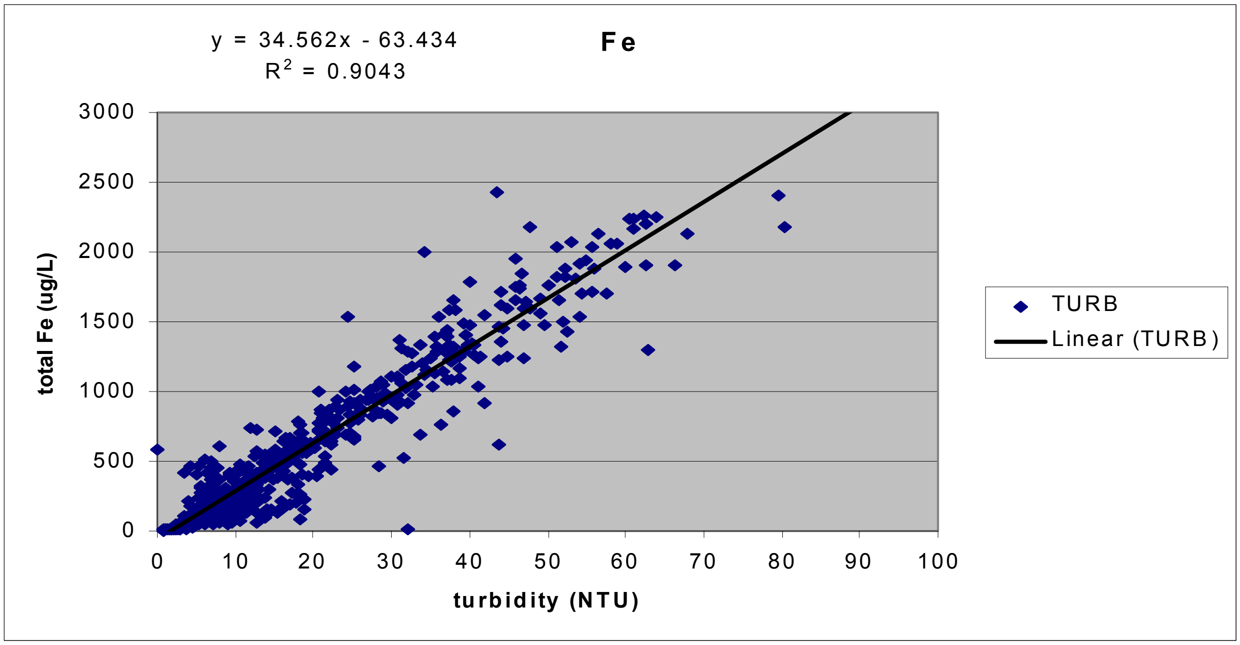

Figure 2. Iron versus turbidity in Lake Okeechobee (from SFWMD).

Iron in the Biscayne Aquifer, which lies below Lake Okeechobee and its watershed, commonly exceeds the 0.3 mg/L drinking water criterion. In addition, ground water movement is such that this iron-rich ground water moves toward the lake. Fernald and Purdum (1998, p. 54), in the Water Resources Atlas of Florida, report iron conditions in various groundwater aquifers in Florida (Figure 3). For the Biscayne Aquifer, the median iron concentration exceeds 1.0 mg/L, and about 75% of the data exceed the 0.3 mg/L criterion. For the Upper Floridan Aquifer, about 50% of the iron data exceed 0.3 mg/L. The median concentration appears to be about 0.2 mg/L, or slightly less than 0.3 mg/L, and the upper quartile is about 1.0 mg/L.

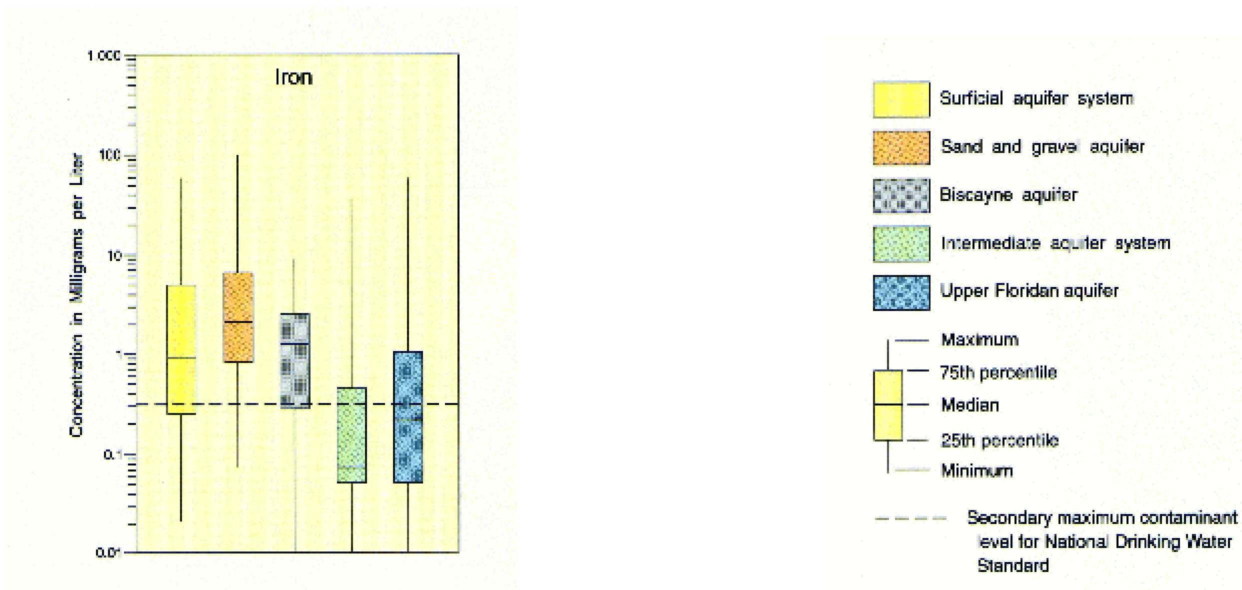

Figure 3. Iron in Florida aquifer systems (from Fernald and Purdum, 1998, page 54).

Fernald and Purdum (1998, p. 267) report areas of recharge or discharge from the Floridan Aquifer system. For the Lake Okeechobee region, they report areas of aquifer discharge to the northwest quadrant of the lake (red area in Figure 4). This means that the major region of surface water discharge into the lake is also an area where iron-rich groundwater is moving from the aquifer into the lake.

Historic reports of iron in the lake were also located. Joyner (1974) reports iron in Lake Okeechobee during 1969-1970. Most values within the Lake were below 0.1 mg/L, although one value of 0.32 is reported. However, occasional values in excess of 0.3 mg/L were reported for Lake tributaries including Fisheating Creek, Harney Pond Canal, Taylor Creek and Nubbin Slough. Joyner reports Lake Okeechobee sediment iron as ranging from 0.5 to 8.1 mg/g dry weight (p. 37).

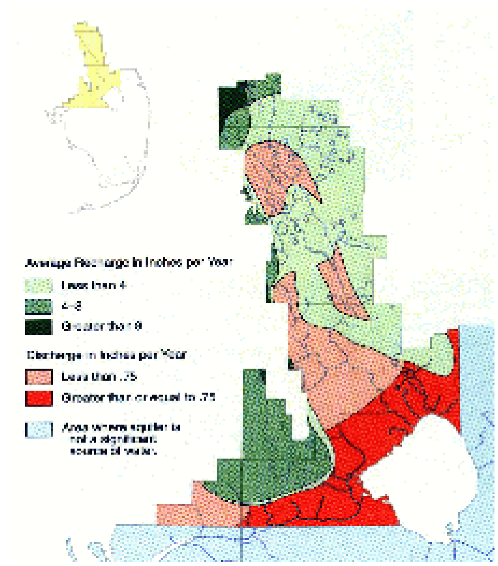

Figure 4. Area of discharge (red) from the aquifer system to Lake Okeechobee (from Fernald and Purdum, 1998, page 267).

The 1987 Surface Water Improvement and Management Plan for Lake Okeechobee contains a review of 1973-1992 water quality data for the lake and tributaries. Exceedences of the lake's 0.3 mg/L iron water quality criteria for drinking water are noted, as are exceedences of the 1.0 mg/L water quality criterion for lake tributaries (Class III waters). The text states that "The widespread distribution and frequency of high iron concentrations in the inflows indicates that this is a natural condition, although agricultural practices could contribute to elevated iron concentrations in surface waters by erosion of soils containing iron and applications of iron-containing fertilizers to crops." (SFWMD, 1987, p. 3-40). Water quality is summarized at nine in-lake stations. "All of the in-lake stations had exceedences of this criterion, with a range of 30% to 75% of observations. Iron was the most notable parameter with exceedences that could affect drinking water quality, perhaps causing objectionable taste, and staining of dishes and clothes. The widespread distribution of high iron concentrations in the lake (and inflows) indicates that this is a natural condition. The most likely source is local soils." (SFWMD, 1987, p. 3-62).

4.4 Iron is common in south Florida surface water and ground water

Iron concentrations in excess of the 0.3 mg/L drinking water criterion are commonly reported in groundwater and surface waters throughout much of south Florida.

Love (1955), in a 1940s study of ground water and surface water throughout southeast Florida, states that iron is dissolved from practically all soils and rocks. He states that surface waters in southeast Florida generally have less than 0.1 mg/L iron but groundwater may contain from a few hundredths of a mg/L to 3 or 4 mg/L and even larger amounts have been found in some wells (p. 731). He reports iron in the Kissimmee River and various canals at around 0.1 mg/L. He reports some Lake Okeechobee water quality, but no data for iron. He reports iron in various non-artesian wells in Dade, Broward and Palm Beach counties, typically 0.3 mg/L or higher.

Carter et al. 1973 (p. XI-6) studied the water quality and ecosystem of the Big Cypress Swamp. They report that iron was consistently detected in surface water samples (concentration range from 0.1 to 5.6 mg/L, with most concentrations between 0.3 and 1.0 mg/L). They noted that Finney and Miller (1960) reported that iron concentrations of 0.9 mg/L were found in shallow wells, and higher concentrations were found in deeper wells. They also noted that iron was used in fertilizers in the study area.

Waller (1981) reports on the effects of land use on surface water quality in the East Everglades area of Dade County. He reports iron average concentrations in surface water across various natural, agricultural and residential areas as ranging from 0.110 mg/L to 0.800 mg/L (800 ug/L). He states "There is no apparent increase in trace element concentrations in the water at the other land use areas, except for iron, 800 ug/L at Coopertown which may be a natural occurrence as iron is typically found in high concentrations (greater than 200 ug/L) in the Everglades." (Waller 1981, page 28).

Waller (1982, page 26) reports surface water iron at canal and marsh stations throughout Everglades National Park. He reports an average total iron concentration (108 samples) of 0.723 mg/L, and an average dissolved iron concentration of 0.088 mg/L (286 samples).

5.0 IRON TOTAL MAXIMUM DAILY LOAD

The TMDL process quantifies the amount of a pollutant that can be introduced into a receiving waterbody without exceeding applicable water quality standards. The pollutant load calculated by the TMDL is allocated among contributing point and/or non-point sources. A TMDL is expressed as the sum of all point source loads (Waste Load Allocations, WLA), non-point source loads (Load Allocations, LA), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or other appropriate measure.

FDEP reports that there are 18 domestic and industrial wastewater point sources in the Lake Okeechobee watershed with National Pollutant Discharge Elimination System (NPDES) permits; however, none of them discharge directly into the lake (FDEP 2001b, pages 81-82). Since there are no NPDES permits for discharges into the lake, the Waste Load Allocation for iron is zero. Other potential iron sources to the lake include atmospheric deposition, non-point loads from over 30 basins, and ground water inflow. These sources are difficult to accurately quantify.

The proposed iron TMDL for Lake Okeechobee is most appropriately expressed as a percent reduction because of the largely variable contributions from nonpoint sources and the difficulty linking the load to space (flow) or time. For this computation, EPA used iron data for the entire Lake Okeechobee waterbody, not just the listed WBIDs. Evaluation of the data indicated that concentrations of iron across the Lake WBIDs reflected similar ranges. The same percent reduction was then applied to all three WBIDs in question. The percent reduction from the in-lake average existing condition to that required to meet the 0.3 mg/L water quality criterion is calculated as follows:

$$\text{Percent Reduction} = [(\text{existing concentration} - \text{target})/(\text{existing concentration})] * 100 + \text{margin of safety}$$

$$\text{TMDL}_{[\%\ \text{reduction}]} = [(0.574 - 0.300)/(0.574)] * 100 + 3 = 51$$

All of this 51 % reduction is attributed to the Load Allocation since there are no point sources of iron in this waterbody.

Waterbody	WLA	LA	MOS	TMDL
WBIDs 3212D, 3212E, 3212G	0	51%	Explicit (3%)	51%

5.1 Load Allocation (LA)

The allowable LAs is expressed as a 51% reduction in concentration of loads to the lake to result in an in-lake concentration that could ultimately achieve the water quality criteria. It should be noted that the LA includes loading from stormwater discharges that are not regulated by the NPDES stormwater permitting program.

5.2 Margin of Safety (MOS)

There are two options for incorporating a MOS in a TMDL: (a) implicitly by using conservative model assumptions to develop allocations; or (b) explicitly by specifying a portion of the TMDL as the MOS and using the remainder for allocations. An explicit MOS is incorporated in this TMDL of 3%.

5.3 Critical Conditions

Critical conditions are attributed to excessive turbidity, which can occur at any time of the year or location in Lake Okeechobee. EPA used all data for this calculation regardless of associated turbidity.

5.4 Seasonal Variation

EPA accounted for seasonality by using data from all seasons over a six year period. Iron concentrations did not appear to be affected by seasonal conditions.

6.0 FUTURE EFFORTS

At this time the prevalence of iron in Lake Okeechobee appears to be attributable to non-anthropogenic sources. The predominant scientific viewpoint is that iron is natural, and can be attributed to ground water, watershed soils, or particulate matter in the Lake, as opposed to atmospheric sources or anthropogenic point or non-point sources. This is not to suggest that there are no anthropogenic activities in the watershed that may contribute iron, such as agricultural activities. It is a question of whether potential anthropogenic sources are significantly raising iron levels above those natural levels otherwise observed. It is currently not possible to calculate an accurate iron budget for Lake Okeechobee. To the extent that surface water iron in the lake is driven by turbidity within the lake, efforts in lake tributaries to control iron at point sources or non-point sources (the consequence of a TMDL) will have little effect or no effect on in-lake iron.

USEPA suggests that the issue of iron levels in Lake Okeechobee be studied during the next basin cycle. Two issues should be addressed at that time. The first is the appropriateness of the 0.3 mg/L drinking water criterion for the lake considering natural background conditions. The second is quantifying anthropogenic sources of iron from all basins and determining whether those sources significantly impact iron levels in the lake.

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APPENDIX A

IRON DATA FOR LAKE OKEECHOBEE

See Data File (Excel File) on EPA Website with Lake Okeechobee Iron TMDL Proposal